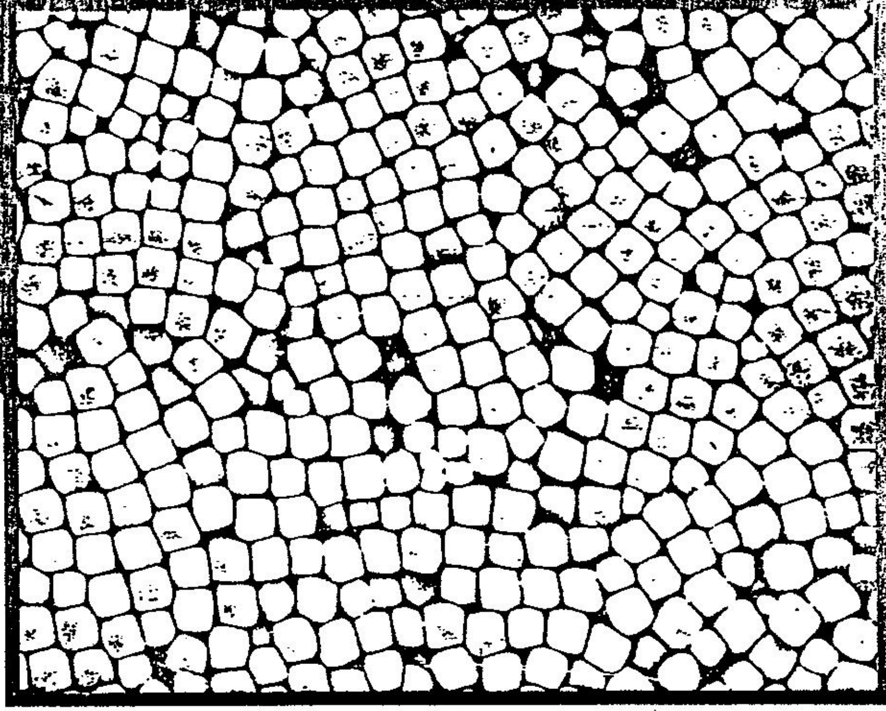
6

GEOCHEMISTRY AND MINERAL FORMATION IN THE EARTH SURFACE



Proceedings of the International Meeting «Geochemistry of the Earth Surface and Processes of Mineral Formation» held in Granada (Spain) 16-22 March 1986

Edited by R. Rodríguez-Clemente and Y. Tardy

• • •

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

DIAGENETIC CRYSTALLIZATION RHYTHMITES (DCRs) OF DOLOMITE - BARITE - CALCITE IN KARST ENVIRONMENT, GEBEL ABU GHORBAN, RED SEA COASTAL ZONE, EGYPT

M.M. El Aref* and S. Ahmed**

* Cairo University, Faculty of Science, Geology Department

** Zagazig University, Faculty of Science.

ABSTRACT

A small strata-bound barite occurrence located in the Middle Miocene evaporites of the Red Sea was systematically investigated. The barite is mostly confined with karstic features within an intercalated dolostone layer. It occurs together with dolomite, calcite and anhydrite mainly in a cement-filled cavity. The geometric distributions proved that these minerals were developed during syndiagenetic crystallization generations corresponding to the diagenetic crystallization rhythmites (DCRs). The genetic argument of this barite type may explain the mechanism of the rhythmic formation in Karst.

INTRODUCTION

The present work is an attempt to understand one type of rhythmic barite texture developing in karst. Small barite occurrence, located in the western side of Gebel Abu Ghorban, Red Sea, has been assigned for investigation, Gebel Abu Ghorban occurs in the coastal zone of the Red Sea, 55 Km S. of Quseir and 3 Km S. of Um Gheig lead-zinc mine (Fig. 1a).

The data are based mainly on the field observations supported by detailed investigations of oriented polished slabs and petrographic studies. Besides, geometric relationships, as recorded in the field and under the microscope are répresented and classified. The present observations revealed the congruent relation between the barite and karst features and suggest the space and time of the crystallization of the barite during the diagenetic differentiation of the karst cementing materials.

Noteworthy, the main barite deposit of the Red Sea coast occurs in Wadi El Gerera (Elba region), 500 Km S. of Quseir. This deposit is of vein type and it was assumed previously to be of hydrothermal origin.

GENERAL GEOLOGY AND LITHOSTRATIGRAPHY

The area of Gebel Abu Ghorban occupies about 6 square Km. It is covered mainly by sedimentary rocks of Middle Miocene age and Recent terraces. These sediments overlay unconformably the Pre-Cambrian basement rocks which represent the western high ridges of the Red Sea coast. The sedimentary outcrops are of relatively moderate to low relief. Their elevation decreases generally towards the present shore line to the east. The most conspicuous hill in Gebel Abu Ghorban rises up to 207 m above sea level.

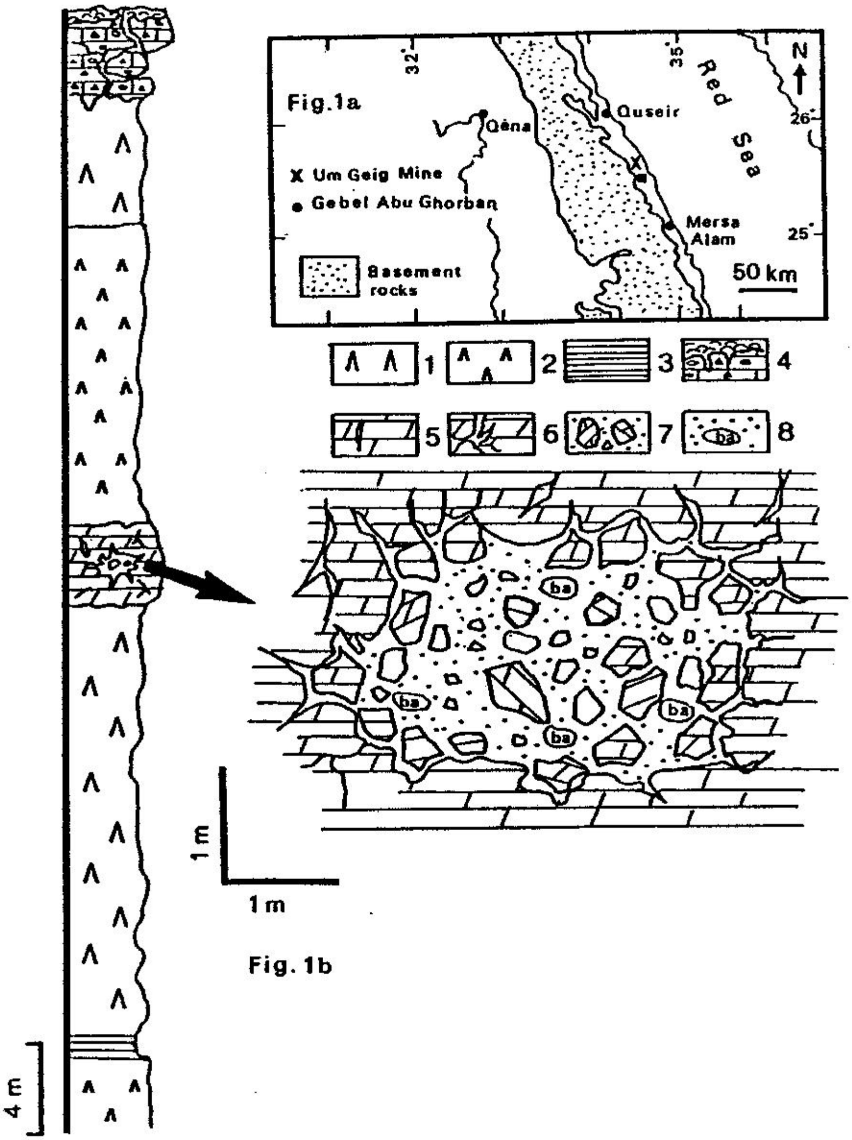


Fig. 1 ; a) Location map; b) Generalized lithostratigraphic section of the Abu Dabbab Formation in the western side of Gebel Abu Ghorban and schematic drawing of the karst filling cavity. 1 = gypsum ; 2 = anhydrite ; 3 = shale; 4 = karstified & silicified limestone encrusted by surficial calcareous crusts ; 5 = karstified dolostone ; 6 = crackle breccia ; 7 = collapsed breccia fragments, 8 = tufaceous materials with barite nodules (ba).

The Middle Miocene sediments in the study area are differentiated into the following two formations considering the nomenclature of the National Stratigraphic Subcommittee classification of the Miocene rocks of Egypt (El Gezeery and Marzouk, 1974). They are arranged from the oldest to the youngest:

- Gebel El Rusas Formation
- Abu Dabbab Formation

Gebel El Rusas Formation consists mainly of bedded marly limestone at the top, and a thin succession of sandstones and conglomerates at the base. The rocks of this formation exhibit different erosional and Karst features. Their present topographic surface is highly brecciated and silicified and characterized by the deposition of surficial calcareous crusts of "caliche" type (El Aref, 1981 ; El Aref and Amstutz, 1983 and El Aref et al, 1985). Abu Dabbab Formation makes up the main sedimentary outcrops in the area of Gebel Abou Ghorban. This Formation, in the western side of Gebel Abu Ghorban, attains a thickness of about 50 m (Fig. 1b). It consists mainly of alternated gypsum and anhydrite with shale intercalation and caped by fractured and brecciated limestone. A layer of dolostone, up to 3 m thick occurs intraformationally within the middle part of these evaporitic rocks. The uppermost exposed surfaces of this formation are also characterized by the development of surficial calcareous crusts. These crusts show features suggesting a downwards deposition by water percolation to karstified substrata.

KARST FEATURES

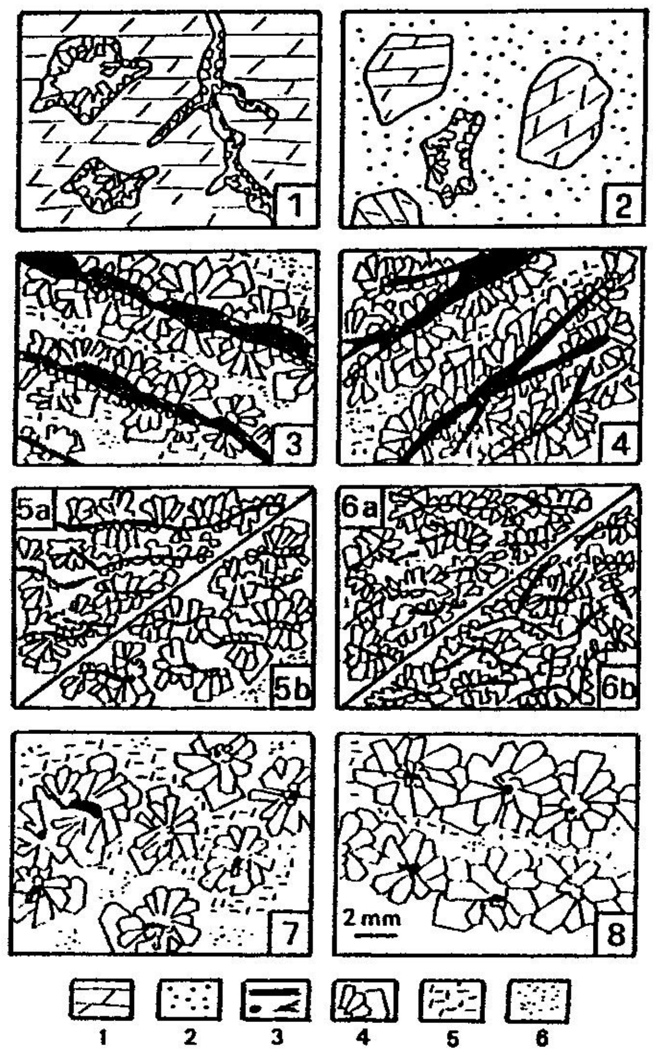
The Middle Miocene rocks in the area of Gebel Abu Ghorban represent a distinctive karst landform. It is dominated by cone hills and cockpits forms and characterized by the development of solutional features forming cavities and erosional surfaces. The cavities are commonly recognized at the contacts between the sediments and the underlying basement rocks, as well as between the two Middle Miocene formations and/or within the carbonate layers. The upper exposed surface of both formations are dissected by vertical and horizontal solutional channels, cracks and veinlets which grew usually in all directions giving rise to brecciation. These surfaces are caped by silicified surficial calcareous crusts of "caliche type".

The dolostone layer, interbedded in the evaporitic succession of the Abu Dabbab Formation contains a semirounded solutional cavity, up to 2x3 m in diameter (Fig. 1b and Fig. 3a). The cavity is completely filled with variable proportions of fragments embedded in very fine and partially consolidated calcareous material. These fragments are of subangular to subrounded shape ranging in diameter from cobbles to fine pebbles and sand sizes. They are mostly of dolostone composition and derived mainly from the roofs and walls of the cavity (Fig. 3b). The proper dolostone is commonly fractured. Some of these fractures are concentrated around the filling cavity forming crackle breccia.

The matrix of the cavity consists mainly of spongy porous calcareous material resembling the calcareous tufa of Irion and Müller (1968). Microscopically, these materials are made up of irregular clot-like masses or network streaks of brownish micrite connected and encrusted by clearer and coarser grained calcite, up to 50 μ in diameter. They may be remains of algal filaments or laminae and moss debris (Fig. 3c). These materials include geodes and nodular forms of barite together with dolomite, zoned calcite and anhydrite.

GEOMETRIC CONSIDERATION

The barite crystals are found mainly within the dolostone layer of the Abu Dabbab Formation. In particular, they are confined within the solutional



}. 2 : Geometric distribution patterns of the barite with
ɪematic simplification of the subsequent rhythmic crystallization
ɪerations (description in the text). Scale in square No. 1 1 =
.ostone ; 2 = tufaceous materials of the filling cavity ; 3 =
ɪe grained dolomite with algal laminae and micro-organic struc-
·es (generation I) ; 4 = barite of different morphologic forms
ɪneration II) ; 5 = calcite ; 6 = anhydrite (5 & 6 = generation
).

karst features displaying the following geometric forms and types (types 1-8 in Fig. 2):

a) symmetrical filling of solutional fractures, cracks and grooves within the proper dolostone (type 1 in Fig. 2).
b) drusy filling of geodes, vugs and grooves within the tufaceous matrix of the solutional filling cavity (type 2 in Fig. 2).
c) barite nodules within the tufaceous matrix of the filling cavity (Fig. 3d). These barite nodules range between 5-15 cm in diameter and display the main barite forms in the studied occurrence.

The megascopic and microscopic observations on the oriented cross-cut slabs and thin sections of the barite nodules disclosed that they are formed by rhythmic alternations of dark and light bands and streaks (Fig. 3e). The dark areas are of brown colour and consist of fine grained dolomite together with algal laminae (Fig. 3f), whereas the light bands consist of barite with or without calcite and anhydrite. The different geometric types of the barite rhythmites, considering the shape of the dark areas, are drawn and classified in Fig. 2 (types 3-8). Type 3 represents alternating parallel to subparallel bands, up to 5 mm thick. Their upper surfaces exhibit U-shaped grooves or groove-cast like texture (Fig. 3e). In type 4 of Fig.2, the dark bands are usually branched into thinner connected or disconnected fine streaks, but still showing a layering appearance. Type 5a represents parallel undulated thin streaks or laminae. They range between 0.5-2 mm in thickness and may branch in some instances. Type 5b is a thin interrupted streaks of wavy appearance forming flaser like structure. However, type 5a could be considered as a transitional pattern between types 4 and 5b. In type 6a, the wavy interrupted streaks are branched forming transitional pattern between types 5a, 5b and type 6b (Fig. 4a). Type 6b displays an interconnected network pattern consisting of branched and connected streaks (Figs. 4a and b). Types 7 and 8 represent a spherulitic or "orbicular"-like (Fontboté, 1981) pattern of barite crystals with or without a center of dark spots. The barite spherulites are either irregularly distributed (type 7) or connected with each other having a layering appearance (type 8).

SEQUENCE OF CRYSTALLIZATION

The microscopic observations do indicate that the rhythmic characters of the barite nodules are due to the repetition of three subsequent generations of crystallization. These observations are based on the study of the morphology of the mineral constituents within the barite nodules and their internal geometric relationships. The subsequent rhythmic crystallization generations are schematically simplified in Fig. 2. Generation I (called starting sheet by Fontboté, 1981) is represented by the dark bands, streaks or spots. It consists of cloudy aggregates of fine grained dolomite together with filaments of algal laminae and cellular organic structures. Generation I is usually stained with reddish brown colours probably due to the existence of organic matter. Generation II forms the major part of the light rhythmic bands (Figs. 4a and b). It consists mainly of barite crystals of different sizes and shapes. They are symmetrically arranged in bipolar patterns growing in both sides of the starting sheet (generation I). Generation II exhibits commonly geopetal growth and contains no solid inclusions. According to the differences of the morphology and size of the barite crystals, generation II is distinctly divided into three subgeneration : a,b and c. Subgeneration IIa is displayed by very fine to fine barite crystals, ranging between 0.05 to 0.3 mm in diameter. They are of subhedral forms and directly deposited on the outer surfaces of generation I. The contact between generation I and subgeneration IIa is abrupt indicating the change in phases during the crystallization. The crystals of subgeneration IIa are xenomorphic towards generation I and show subhedral termination into subgeneration IIb. Subgeneration IIb is displayed by slightly to notably elongate and bladded shaped barite crystals, ranging between 0.5 to 2.5 mm in diameter. These crystals are usually arranged in spherulitic pattern or flower like aggregates or they are of radial orientation (Figs. 4c and d). Subgenera-

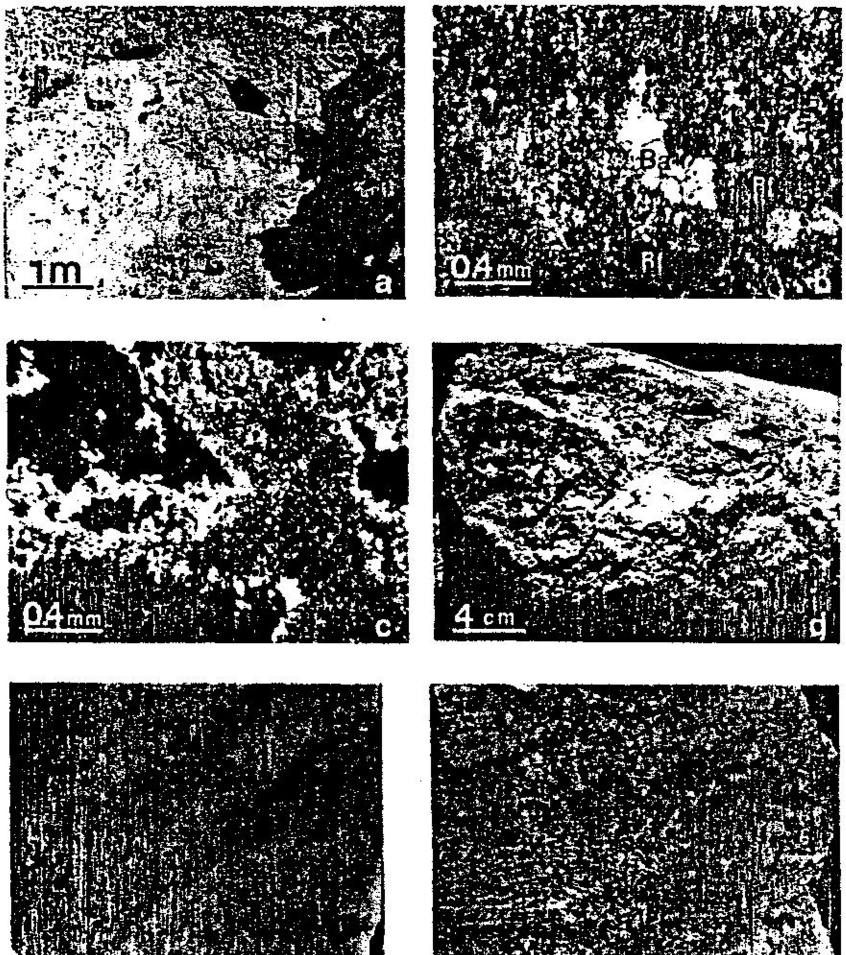


Fig. 3: a) Field photograph of the karst filling cavity (arrow). b) Photomicrograph (//N) of the cavity filling material consisting of rock fragments (Rf) embedded in calcareous tufaceous matrix. The matrix includes drusy filled geodes of barite (Ba). c) Photomicropgraph (+N) of the "tufaceous" matrix of the cavity consisting of spongy porous calcareous material. d) Barite nodule (Ba) embedded in the calcareous matrix of the filling cavity. e) Polished slab of barite "DCR". The dark bands consist of fine grained dolomite (generation I) and the light bands consist of barite (generation II). Generation III is not visible. f) Polished slab showing filaments of algal laminae (arrow) in generation 1.

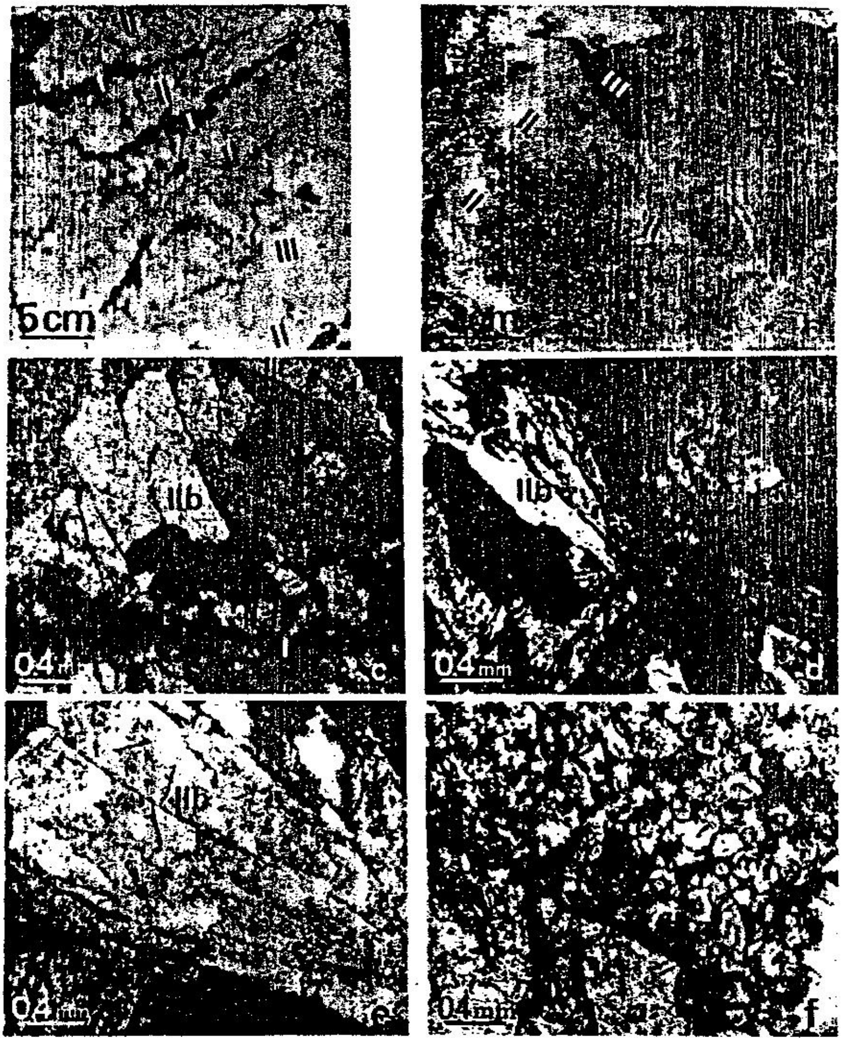


Fig. 4 : a) Thin section (//N) of rhythmic dolomite (generation I) and barite (generation II).GenerationIII is represented by empty voids (white). Generation I forms interrupted, wavy, parallel and branched streaks gradually changed to network pattern (Left corner of the photo). Notice, the geopetal growing of generation II into generation III. b) Polished slab of network rhythmic type corresponding to type 6b of Fig. 2. c) Photomicrograph (+N) showing the development of the differenct generations I, II and III and subgeneration IIa, IIb and IIc. Generation III is displayed by felty anhydrite. d) Spherulitic growth of barite crystals showing the encrustation of subgeneration IIb by subgeneration IIc (photomicrograph, +N). e) Barite crystals of subgeneration IIb followed by the crystallization of subgeneration IIc (photomicrograph, +N). f) Euhedral barite crystal of subgeneration IIc (Left corner of the photo) encrusted by basic hexagonal shaped and zoned calcite (photomicrograph, +N).

tion IIa shows graditional development into subgeneration IIb. The subgeneration IIb has idiomorphic ends towards subgeneration IIc and generation III (Figs. 4d and e). Subgeneration IIb is caped in some instances by almost euhedral and relatively large barite crystals which form the subsequent subgeneration IIc in the crystallization sequence (Fig. 2 and Figs 4d and e) and which ranges in diameter between 1-3 mm. From the geometric point of view , it could be concluded that the morphologic subdivisions of generation II represent different growth stages produced subsequently during the crystallization of this monomineralic barite phase. Generation III is mainly displayed by the development of the residual empty spaces left by generation II. In some instances, these spaces are partially lined or completely filled by calcite and/or felty anhydrite. The calcite occurs as aggregates of equidimensional basic hexagonal, granular or wedge shaped and zoned crystals usually stained by a reddish colouration (Fig. 4f). These characteristic morphologic forms of calcite suggest a fresh water origin according to the description of Krumbein, 1968 and Folk, 1974. The calcite of generation III fills the spaces between generation II and is usually followed by the deposition of the felty anhydrite.

GENETIC IMPLICATION

The barite occurrence of Gebel Abu Ghorban is typically strata-bound. It is mostly confined within the karst filled cavity included in the dolostone layer of the Abu Dabbab Formation.

The megascopic and microscopic observations revealed that the barite crystals are closely associated with cryptalgal laminae, fine grained dolomite, calcite and anhydrite. These minerals and the associated organic remains are symmetrically arranged in rhythmic textures of different geometric patterns. The observed characteristic rhythmites are due to repetition of three subsequent crystallization generations, i.e. fine grained dolomite with cryptalgal laminae, barite crystals with different morphologic forms and primary empty spaces (vugs) filled with calcite and/or anhydrite. The type of the rhythm could be expressed as CBABC. The evidences for the paragenetic positions of the above mentioned minerals are determined from the follwoing recognizable features ; a) the bipolarity, spherulitic growth, subhedral termination, idiomorphism and the change of size of the barite crystals of generation II, and b) the infilling of the remaining spaces and the development of the primary empty voids of generation III. The morphologic characters of the barite crystals reflect the primary relative rate of growth of the crystal faces according to the equilibrium condition of the medium (Rodriguez - Clemente, 1982).

The geometric distribution patterns of these rhythmites may be interpreted as primary sedimentary fabrics including layering laminae, streaks, wavy or flaser bedding, geopetal growth and groove-cast. The cross cutting or network fabrics seem to be formed as a result of the deformational processes caused during the crystal enlargement. These geometric patterns correspond to types D, F, H and S of the classification of the ore rhythmites of Levin and Amstutz (1976) and are comparable with types 3, 4a, 4b and 9 of the classification of Fontobté (1981) for the basic geometric patterns of diagenetic crystallization textures.

Moreover, the lack of any evidence of replacement, corrosion or pseudomorphism in generation II, lead to the conclusion that the present rhythmites were developed during processes of fractionation crystallization and differentiation that took place before the consolidation of the rocks, e.g., during the diagenesis, in a closed karst environment, (called diagenetic crystallization rhythmites "DCRs" by Fontbote and Amstutz, 1980). The main features of the different crystallization generations of the observed rhythmites are closely similar to those of the diagenetic rhythmites of Fontboté and Amstutz, 1982. The diagramatic representation of the barite DCRs of

Gebel Abu Ghorban is illustrated in Fig. 5. The formation of barite in karst

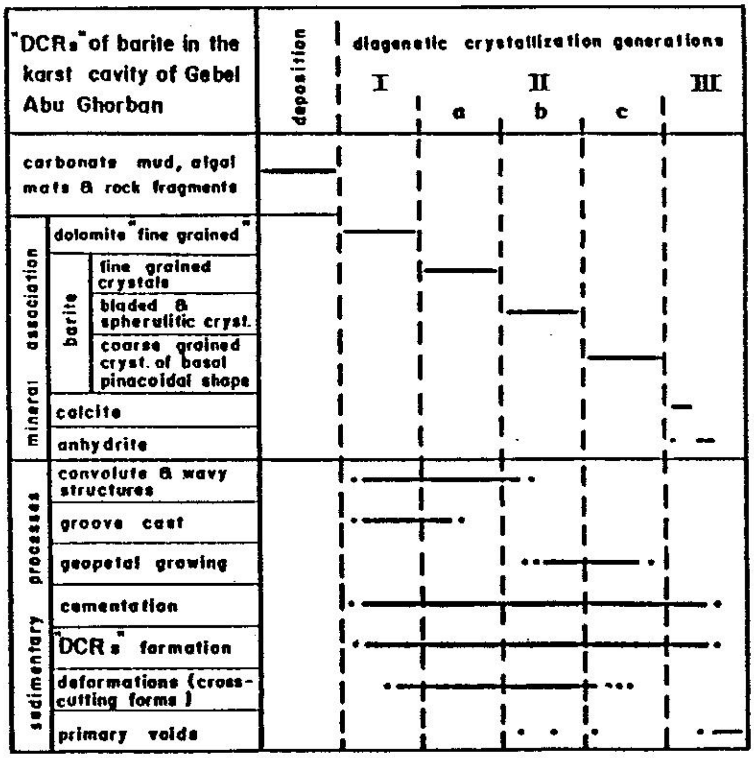


Fig. 5 : Schematic paragenetic sequence of the barite "DCRs" of Gebel Abu Ghorban.

characterises the percolation zone of the karst model by Bernard (1976) and Zuffardi (1976).

The rhythmic diagenetic crystallization was proposed previously by Amstutz and Park (1967) and Amstutz and Bubenicek (1967). Reviews and description of different occurrences of ore rhythmites in marine facies, have been presented in Levin and Amstutz, 1976 ; Fontboté and Amstutz, 1980 ; Fontboté, 1981 ; Fontboté and Amstutz, 1982 and Samaniego, 1982. Synsedimentary rhythmicity of barite in Arkansas, Nevada and Meggen (Germany) were described by Zimmermann (1967, 1969, 1970 and 1976) and Zimmermann and Amstutz (1961 and 1964 "a,b,c"). DCRs in Egypt is recently described by El Aref (1984) for the iron sulphide and sulphur occurrences of the Ranga mine and by El Aref et al (1985) for the crystallization of surficial calcareous crusts of caliche type.

Megascopic rhythmic textures of ores were observed in Karst by Bernard, 1976 ; Padalino et al, 1976 ; Zuffardi, 1976 ; Schulz, 1976 and 1982. These authors support the syndiagenetic origin of the ore rhythmites. While, Bogacz et al. (1973) still proposed metasomatic replacement origin for the ore rhythmites in open cavities.

The development of the karst features and the associated barite DCRs of Gebel Abu Ghorban appear to be genetically related to the formation of the karst filling mass of Um Gheig mine (El Aref and Amstutz, 1983) and the deposition of the surficial calcareous crusts of the "caliche" type (El Aref, 1981 and El Aref et al, 1985). Regarding the age of the karstification and barite formation, it seems to be younger than the Middle Miocene sediments,

most probably Pliocene or Pleistocene.

REFERENCES

Amstutz, G.C. and Bubenicek, L. (1967):"Diagenesis in sedimentary mineral deposits. In: G. Larsen and G.C. Chilingar (eds) Diagenesis in sediments. 8." Elsevier, Amsterdam, 417 - 475.

Amstutz, G.C. and Park, W.C. (1967):"Stylolites of diagenetic age and their role in the interpretation of the southern Illinois fluorspar desposits". Min. Dep. 2, 44 - 53.

Bernard, A.J. (1976): "Metallogenic processes of intra-karstic sedimentation. In: Amstutz, G.C. and Bernard, A.J. (eds.) Ores in Sediments." Springer, Berlin-Heidelberg, 43-57.

Bogacz, K. ; Dzulynski, S.; Haranczyk, C. and Sobczynski, P. (1973): "Sphalerite ores reflecting the pattern of primary stratification in the Triassic of the Cracow - Silesian region", Rocznik Polskiego Towarzystwa Geologicznego Annales de la Société Geologique de Pologne, XLIII, 285 - 300.

El Aref, M. (1981): "Lead-zinc deposits along the Red Sea coast of Egypt. New observations and genetic models on the occurrences of Um Gheig, Wizr, Essel and Zug El Bohar". Ph. D. thesis, Heidelberg Univ. 136 p.

El Aref, M. (1984): "Strata-bound and stratiform iron sulphides, sulphur and galena in the Miocene evaporites, Ranga, Red Sea, Egypt (with special emphasis on their diagenetic crystallization rhythmites) In : Wauschkuhn et al. (eds). Syngenesis and epigenesis in the formation of mineral deposits." Springer Verlag, Heidelberg. 457 - 467.

El Aref, M.M.and Amstutz, G.C. (1983) : "Lead-zinc deposits along the Red Sea coast of Egypt. New observations and genetic models on the occurrences of Um Gheig, Wizr, Essel and Zug El Bohar. Monograph series on mineral deposits." Gebrüder Borntraeger, Berlin, Stuttgart, No. 21, 103 p.

El Aref, M.M. ; Abdel Wahab, S. and Ahmed, S. (1985) : "Surficial calcareous crust of caliche type along the Red Sea coast, Egypt." Geologische Rundschau, 74/1, 155 - 163.

El Gezeery, M. and Marzouk, I, eds. (1974): "Miocene rock stratigraphy of Egypt. Stratigraphic Sub-Committee of the National Committee of Geological Sciences." Egypt. J. Geol., 18, 1 - 69.

Folk, R.L. (1974) : "The natural history of crystalline calcium carbonate : effect of Magnesium content and salinity." J. Sed. Pet., 44, 1, 40-53.

Fontboté, L. (1981) : "Strata-bound Zn-Pb-F-Ba deposits in carbonate rocks : New aspects of paleogeographic location, facies factors and diagenetic evolution (with a comparison of occurrences from the Triassic of Southern Spain, the Triassic / Liassic of Central Peru and other localities)". Ph. D. Thesis, Univ. Heidelberg, 192 p.

Fontboté, L. and Amstutz, G.C. (1980): "New observations of diagenetic crystallization rhythmites in the carbonate facies of the Triassic of the Alpujarrides (Betic Cordillera, Southern Spain). Comparison with other diagenetic rhythmites". I symp. Diagenesis. Barcelona, 1980. Rev. Inst. Inv. Geol., 34, Barcelona. 293 - 310.

Fontboté, L. and Amstutz, G.C. (1982): "Observations on ore rhythmites of the Trzebienka Mine, Upper Silesian-Cracow Region, Poland, In : Amstutz et al (eds), Ore genesis, the state of the art". Springer Verlag, Berlin, Heidelberg, 83 - 90.

Irion, G. and Müller, G. (1968) : "Mineralogy, petrology and chemical composition of some calcareous tufa from the Schwabische Alb, Germany. In : Müller, G. and Friedman, G.H. (eds). Recent developments in carbonate sedimentology in central Europe". Springer Verlag, Berlin, Heidelberg, 157 - 171.

Krumbein, W.E. (1968) : "Geomicrobiology and geochemistry of the "Nari-lime-crust" (Israel). In : Müller, G. and Friedman, G.M. (eds.) Recent developments in carbonate sedimentology in central Europe". Springer Verlag, Berlin, Heidelberg, 138 - 147.

Levin, P. and Amstutz, G.C. (1976) : "Kristallisation und Bewegung in Erzrhythmiten am Beispiel triassische - jurassischer Lagerstätten in Ostperu. Muenstersche Forsch." Geol. Palaeontol. 38/39 ; 111 - 128.

Padalino, G. : Pretti, S. ; Tamburrini. D ; Tocco, S : Uras, I ; Violo, M ; and Zuffardi, P. (1976) : "Ore deposition in karst formations with examples from Sardinia. In : Amstutz, G.C. and Bernard, A.J. (eds). Ores in sediments". Springer, Berlin, Heidelberg, 209 - 220.

Rodriguez - Clemente, R. (1982) : "The crystal morphology indicator". Estudios Geol., 38, 155 - 171.

Samaniego, A. (1982) : "Correlation of strata-bound mineral deposits in the Early Cretaceous Santa Metallotect of North and Central Peru. In : Amstutz. G.C. et al (eds). Ore genesis the state of the art". Springer Verlag, Berlin, Heidelberg. 508 - 527.

Schulz, O. (1976) : "Typical and nontypical sedimentary ore fabrics. In Wolf, K.H., (ed). Handbook of strata-bound and stratiform ore deposits, V. 3, supergene and surficial ore deposits ; Texture and fabrics". Elsevier, Amsterdam, 295 - 338.

Schulz, O. (1982) : "Karst or thermal mineralization interpreted in the light of sedimentary ore fabrics. In : Amstutz et al, (eds). Ore genesis, the state of the art". Springer Verlag, Heidelberg, 108-1171

Zimmermann, R.A. (1967) : "Sedimentary features in the layered barite deposits of Nevada, Wisconsin and Meggen (Germany)". In. Int. Sediment. Cong. 7th, Great Britain, 1967. Reprint.

Zimmermann, R.A. (1969) : "Strata-bound barite deposits in Nevada ; rhythmic layering, diagenetic features, and a comparison with similar deposits of Arkansas". Miner. Deposits, 4, 401 - 409.

Zimmermann, R.A. (1970) : "Sedimentary features in the Meggen barite-pyrite-sphalerite deposit and a comparison with the Arkansas barite deposits". Neues Jabrb. Miner Abh. 113 : 179 - 214.

Zimmermann, R.A. (1976) : "Rhythmicity of barite-shale and of Sr of in Strata-bound deposits of Arkansas. In : Wolf (ed) Handbook of Strata-bound and stratiform ore deposits. V.3, supergene and surficial ore deposits, textures and Fabrics". Elsevier, Amsterdam, 339 - 353.

Zimmermann, R.A. and Amstutz, G.C. (1961): "Sedimentary features in the Arkansas barite belt". Geol. Soc. Am. Bull., 68 ; 306 - 307..

Zimmermann, R.A. and Amstutz, G.C. (1964)a : "Small scale sedimentary features in the Arkansas barite district. In : G.C. Amstutz (ed), Sedimentology and ore genesis (Development in sedimentology, 2". Elsevier, Amsterdam, 157 - 163.

Zimmermann, R.A. and Amstutz, G.C. (1964)b : "Die Arkansas - Schwerspatzone: neue sediment petrographische Beohachtungen und genetische Umdeutung". Erzmetall, 363 - 371".

Zimmermann, R.A. and Amstutz, G.C. (1964)c: "Genesis of layered barite deposits in Arkansas and Germany - (abs.)." Geol. Soc. Am. Spec. Pap., 82, p. 234.

Zuffardi, P. (1976) : "Karst and economic mineral deposits. In : Wolf, K.H. (ed) Handbook of strata-bound and stratiform ore deposits, V. 3, Supergene and surficial ore deposits ; textures and fabrics". Elsevier, Amsterdam, 175 - 212.